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A STUDY OF THE FLIGHT ENVIRONMENT COMPONENT

OF AIRCREW FATIGUE IN STUDENT NAVIGATORS

Douglas R. Douville, M.D.
The University of Texas
Health Science Center at Houston
School of Public Health, 1985

Supervising Professor: Spurgeon Neel, M.D.

Flying has long been known as an activity producing an inordinate amount of fatigue. The source of this fatigue has never been well understood. One approach to understanding the causes of aircrew fatigue is to divide them into (1) those related to the unique demands of aircrew tasks or workload and (2) those related to the unique environment of flight. The pilot not only has to navigate, make radio calls and negotiate instrument landings, but he must do it all in a noisy, vibrating, constantly moving environment. Most studies in aircrew fatigue focus on the workload part of the equation. The study described in this proposal is an attempt to define that part of aircrew fatigue which is due to the flight environment. It also attempts to determine changes in body chemistry produced by the flight environment which might be associated with aircrew fatigue. Navigator students in training at Mather Air Force Base, California, fly training missions of similar duration and quality in T-43 aircraft and ground simulators. The difference in fatigue and body chemistries after flights in these two settings represents that which is due to the difference in environments. (after controlling for important variables). Using student navigators as subjects, blood samples would be taken before and after (1) a five hour T-43 (Boeing 737) flight and (2) a five hour ground simulator mission. Changes in a panel of 26 blood chemistries (including plasma osmolality and carboxyhemoglobin) for each setting would be compared for significant differences. Fatigue would be assessed in each setting using (1) a subjective fatigue questionnaire, (2) hours of sleep following the mission, and (3) performance (academic score). Fatigue in the two settings would be compared for significant differences. Statistical analysis would attempt to correlate those chemistries in which a significant change was noted with increased levels of fatigue. Positive correlations would be the basis for further studies to determine whether the relationship was causal.

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AUTHOR: Douglas R. Douville

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A STUDY OF THE FLIGHT ENVIRONMENT COMPONENT

OF AIRCREW FATIGUE IN STUDENT NAVIGATORS

By

DOUGLAS R. DOUVILLE, M.D.

APPROVED:

Spurgeon Neel, M.D., M.P.H.

Robert Oseasohn, M.D.

A STUDY OF THE FLIGHT ENVIRONMENT COMPONENT OF AIRCREW FATIGUE IN STUDENT NAVIGATORS

By

DOUGLAS R. DOUVILLE, M.D.

A PROJECT PROPOSAL

Presented to the Faculty of The University of Texas

Health Science Center at Houston

School of Public Health

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF PUBLIC HEALTH

THE UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER AT HOUSTON
SCHOOL OF PUBLIC HEALTH
Houston, Texas
June 1985

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subjects, blood samples would be taken before and after (1) a five hour T-43 (Boeing 737) flight and (2) a five hour ground simulator mission. Changes in a panel of 26 blood chemistries (including plasma osmolality and carboxyhemoglobin) for each setting would be compared for significant differences. Fatigue would be assessed in each setting using (1) a subjective fatigue questionnaire, (2) hours of sleep following the mission, and (3) performance (academic score). Fatigue in the two settings would be compared for significant differences. Statistical analysis would attempt to correlate those chemistries in which a significant change was noted with increased levels of fatigue. Positive correlations would be the basis for further studies to determine whether the relationship was causal.

INTRODUCTION

If one were to question the importance of aircrew fatigue, they would have only to think back to the night of 24 April, 1980. On a dark stretch of the Iranian Great Salt Desert, 250 miles southeast of Tehran, an attempt to rescue the American Embassy hostages met with tragedy when the pilot of a Navy RH-53 Sea Stallion helicopter turned too sharply and struck an Air Force C-130 transport plane.[1] Eight U.S. servicemen died in the crash and fire. Shortly before, the pilot of the helicopter had alluded to the stress of making a five hour low level flight without lights.[2] The operation commander later described the appearance of the pilot before the accident as "shattered" from the ordeal of the flight.[3]

From the early years of aviation, the flight environment has been known for its unique ability to cause fatigue. Concern about the effects of flying on the body appeared in The Journal of the American Medical Association in 1914.[4] In Lindbergh's account of the first nonstop flight between North America and Europe, he described feeling considerable dismay at experiencing significant fatigue less than four hours into his

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[1] "Debacle in the Desert," Time, May 5, 1980, p. 14.

[2] Beckwith, Charlie A. Delta Force, (New York, 1983), p. 250.

[3] Ibid., p. 251.

[4] Ovington, E. L. "The Psychic Factors in Aviation," Journal of the American Medical Association, August, 1914, p. 419.

34 hour historic flight.[5] A 1963 survey suggested that three quarters of airline pilots experience significant fatigue.[6]

Flight safety is probably the primary reason aircrew fatigue is such an important concern. In a NATO report on helicopter aircrew fatigue, it was noted that fatigue was a major cause in 20% of 50 helicopter accidents in which a detailed accident report was available.[7] The Air Force attributes at least 55% of its accidents to human error.[8] Sorting out which factors caused an accident due to human error is a difficult task. Fatigue may very well have been a factor in a significant percentage of these.

There are other reasons for studying aircrew fatigue. In the military, how well a mission is performed (operational efficiency) can be affected by fatigue. In combat, performance can determine whether an aircrew comes home.

Stanley Mohler, in a review of fatigue in aviation activities, points out another reason for studying aircrew fatigue--the occupational health implications:

> . . . though a given occupational population continues to turn out a creditable service, it may be doing so under adverse circumstances that ultimately take a toll in terms of permanent protoplasmic alterations.[9]

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[5] Lindbergh, Charles. The Spirit of St. Louis, (New York, 1953), p. 201.

[6] Lodeesen, Marius, and James Crane. "Tired Jet Pilots," Flying, March, 1963, p. 33.

[7] Helicopter Aircrew Fatigue, Advisory Group for Aerospace Research and Development, NATO, Report No. 69, ed. I. C. Perry, May, 1974, p. 4.

[8] Rayman, Russell B. Aircraft Accident Investigation for Flight Surgeons, USAF School of Aerospace Medicine, Review 3-79, March, 1979, p. 4.

[9] Mohler, Stanley R. "Fatigue in Aviation Activities," Aerospace Medicine, July, 1966, p. 728.

Though flyers continue to perform effectively and safely, we must insure there are no adverse effects from this performance.

The purpose of the following research proposal to add to our understanding of fatigue in flight. This is done in hop of making it a safer activity and insuring that it is performed in the most efficient manner possible. In addition, the aircraft cabin is fast becoming part of our day to day environment. It was estimated that in 1980 300 million passengers travelled by air.[10] As we learn more about fatigue in flight, we learn more about this unique and increasingly important environment.

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[10] Harding, Richard, and F. Mills. Aviation Medicine, (London, 1983), Preface.

DEFINITION OF TERMS

Fatigue - Defined in the context of the biologic sciences as a state following a period of mental or bodily activity; or associated with continuous activity characterized by the following items (as outlined by I. C. Perry[11]):

(a) Impairment: This is used to refer to specific tissue conditions, i.e., biochemical or physiologic changes associated with continued work.
(b) Work Output: A change, usually a decrement in the quantity or quality of work, either physical or mental (often called "skill fatigue").
(c) Fatigue: The subjective feelings resulting from continued activity; this activity can be either mental or physical.

Aircrew - Individuals, other than passengers, making regular serial flights; each having an assigned task contributing to the completion of the flight or mission.

Aircrew Fatigue - Fatigue occurring in aircrews as a result of aerial flight.

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[11] Helicopter Aircrew Fatigue, p. 1.

THE CONCEPT OF FATIGUE

Pivotal to creating and interpreting a study in fatigue is an understanding of the implications of the definition of fatigue just presented. In many instances, a fatigue situation includes all three facets of the above definition. A truck driver, having made the trip from Denver to St. Louis in one day, would probably admit to being tired (<u>subjective fatigue</u>). He would probably be slow in unloading his cargo (<u>work output</u>). Last, if we were able to do sophisticated physiologic testing such as binocular fusion, we would likely find <u>impairment</u>.[12] However, one or two parts of the definition may be absent in a fatigue situation and relationships between parts may be obscure or nonexistent. In baseball, the starting pitcher often begins giving up runs in the fifth or sixth inning. This is probably due to fatigue. Yet, if you ask him if he feels tired, he might quite honestly say no. Highly motivated people often do not feel fatigue (subjective) until long after fatigue (as seen in performance or physiologic testing) has set in.

A number of studies have demonstrated that work output can remain the same even in the presence of increasing subjective fatigue.[13] The commonly accepted explanation is that despite the onset of fatigue, work output can be maintained at a given level by increasing amounts of effort.[14]

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[12] Mohler, p. 723.

[13] Pierson, W. R. "Fatigue, Work Decrement and Endurance in a Simple Repetitive Task," <u>British Journal of Medical Psychology</u>, No. 36, 1963, pp. 279-282.

[14] <u>Helicopter Aircrew Fatigue</u>, p. 2.

The effort needed to continue at that level of output becomes less efficient. This can be thought of in terms of the activity exacting an increasing physiologic cost once a state of fatigue is reached. This is seen on a non-cellular level in the additional sleep required after performing a particularly demanding task. In recent studies of fatigue, urinary metabolites, catecholamines, and steroids have been used as indicators of physiologic cost on a cellular level.[15]

Physical fatigue has a number of measurable parameters including decreased strength, increased blood lactic acid, and decreased blood glucose.[16] The measurement of mental fatigue relies more upon subjective parameters such as increased irritability, increased anxiety, and decreased libido.[17] However, there have been useful objective measurements of mental fatigue. Bills has done several studies looking at the phenomenon of "blocking."[18] When performing a repetitive task, involuntary rest pauses are noted. These pauses are referred to as "blocks." "Blocks" predictably increase in frequency and duration with mental fatigue.

Another key consideration is that of acute versus cumulative fatigue. Acute fatigue can be defined as that which can be alleviated by a period of rest. Cumulative fatigue is that which is carried over from

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[15] Miller, Robert G. "Secretion of 17-Hydroxcorticosteroids in Military Aviators as an Index of Response to Stress: A Review," Aerospace Medicine, May, 1968, pp. 498-501.

[16] Mohler, p. 723.

[17] Ibid.

[18] Bills, A. G. "Fatigue, Oscillations, and Blocks," Journal of Experimental Psychology, 1935, 18, pp. 562-573.

day to day because of an inadequate recovery.[19] This "carry-over fatigue" can affect fatigue experienced on subsequent days.

Another important facet of fatigue is workload. Workload involves "performing a given amount of mental or physical work per unit of time."[20] There are three determinants of workload: the objective demands of the work, capabilities of the individual, and the metabolic costs of the work.[21] The importance of these concepts will be apparent as the proposed experimental model is described later.

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[19] Perreli, Layne P. Fatigue Stressors in Simulated Long Duration Flight, USAF School of Aerospace Medicine, Report SAM-TR-80-49, December, 1980. p. 15.

[20] Ibid., p. 13.

[21] Ibid.

FATIGUE IN AIRCREWS

As alluded to in the introduction, the flying environment has great potential for producing fatigue. In analyzing the causes of aircrew fatigue we might divide them into two broad categories. This not only helps explain aircrew fatigue but also, as will be seen later, provides an excellent basis for study. Very simply put, aircrew fatigue is produced by: (1) a unique workload and (2) the stresses of a special environment.

Workload

Most discussions and studies of fatigue in flight single out the pilot. This is probably because the pilot's job is felt to be the most critical and the most stressful. However, for the purpose of this and following discussions, the aircrew will be the subject of interest. This would include pilots as well as other members of the regular flying crew. Besides sharing the unique stresses of the flying environment, aircrew members share uniquely stressful job demands or workloads. This is especially true in military flying. For example, during air-to-air refueling the precarious operation is highly dependent upon the skills of the enlisted boom operator. During naval anti-submarine warfare operations in the P-3 aircraft, the senior navigator is in charge. The pilot simply follows his commands for course and altitude.

The muscular effort required in most types of flying is generally not very great and probably contributes little to the workload component of fatigue. One source of muscular fatigue (some describe as neuromuscular fatigue) is that due to the muscular tone required to maintain posture in

what is at times a confined and uncomfortable position.[22] However, this begins to cross over into the second category of environmentally induced fatigue discussed below.

The primary workload sources of aircrew fatigue are not physical but rather mental and emotional. Though many aspects of flying become automatic, under adverse conditions, such as bad weather or combat, it can be very emotionally and mentally demanding. Also, especially in military flying, it may be necessary to fly for extended periods of time.

It is impossible to separate fatigue secondary to mental demands (or workload) from that due to emotional demands. One reviewer described flying as having unique emotional demands because it is a "vital" rather than a technical activity.[23] By "vital," the implication is that the individual's ego is deeply involved in the activity. How well it is done is extremely important to the individual. The most dramatic example of this concept is that failure to perform adequately can result in loss of not only the flyer's life, but often unbelievable resources. (An Air Force C-5 aircraft costs in excess of sixty million dollars.)

Environment

The other source of fatigue in flyers is the unique environment of flight. Generally accepted environmental sources of fatigue in flight include noise, vibration, changes in barometric pressure, effects of acceleration, deceleration, and spatial disorientation. Another possible environmental cause in pressurized aircraft is the cabin atmosphere with its low humidity and potential for accumulation of noxious gases.

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[22] Rotondo, Guetano. "Workload and Operational Fatigue in Helicopter Pilots," Aviation, Space, and Environmental Medicine, February, 1978, p. 431.

[23] Ibid., p. 430.

No discussion of aircrew fatigue would be complete without mention of circadian rhythm changes. Though one might describe this as part of the unique environment, it seems more appropriately classified as a unique task demand similar to having to fly for long periods of time.

In summary, the sources of aircrew fatigue might be separated into (1) those resulting from the demands of the job and (2) those due to the unique environment of flight. This classification will serve as the basis for the study being proposed.

RECENT STUDIES

Recent research in aircrew fatigue has been performed predominantly by the military. Much of this work has been operationally oriented with interest in, and use of, biochemical indicators of stress. These indicators have in turn been correlated with various measurements of fatigue and performance. A study published by Storm and Merrifield in August 1980 looked at differences between four and five-man C-5A transport crews using a subjective fatigue check list.[24] The purpose of the study was to determine the feasibility of dropping the navigator from the aircraft's crew. A Triple Inertial Navigation System being installed on the aircraft would perform most of the navigation.

Another mission oriented study, published by Storm in 1980, evaluated subjective fatigue, sleep, emotional tone, and various endocrine and metabolic indices of stress in crew members during thirty-hour missions in the E-4B aircraft.[25] Moderate levels of fatigue were noted but not felt to compromise flight safety or performance. Physiologic cost was implied from increased sleep following the mission. The purpose of this study was to demonstrate that an extended mission in the aircraft would not be compromised by crew fatigue.

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[24] Storm, William, and John Merrifield. Fatigue and Workload in Four Man C-5A Cockpit Crews, USAF School of Aerospace Medicine, Report SAM-TR-80-23, August, 1980, pp. 1-43.

[25] Storm, William F. E-4B Crew Fatigue Associated with 30-Hour IOT & E Mission, USAF School of Aerospace Medicine, Report SAM-TR-80-40, October, 1980, pp. 1-20.

In a study published by Hartman, Hale, and Johnson in 1974, the occurrence of subjective fatigue after 8 hour flights in a new fighter-bomber was studied.[26] The purpose of the study was to assess a newly acquired aircraft's acceptability in terms of workload and stress on the crew members. A moderate degree of subjective fatigue was noted. Elevated urine levels of epinephrine, 17-OHCS, urea, and potassium were thought to be consistent with moderate physiologic stress.

In a study published by Harris, Pegram, and Hartman in 1971, different work-rest cycles during long duration missions in C-141 transport aircraft were evaluated.[27] Using a subjective fatigue check list, EEG recordings, sleep survey, and crew performance ratings, no differences between work-rest schedules were noted. However, differences were noted with varying mission profiles and crew positions. Greater fatigue was recorded on missions with greater workload, i.e., missions with more frequent take-offs and landings. No degradation of performance was noted though a physiologic cost was implied by substantial increase in sleep following the missions.

Other military studies have been directed more towards understanding the nature of aircrew fatigue. In an earlier discussion, capability of the individual was listed as a determinant of work load. This would explain the findings in a study published by Kramer, Hale, and Williams.[28] Measurements

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[26] Hartman, Bryce O., and Wayne Johnson. "Fatigue in FB-111 Crewmembers," Aerospace Medicine, September, 1974, pp. 1026-1029.

[27] Harris, D. A., and others. "Performance and Fatigue in Experimental Double-Crew Transport Missions," Aerospace Medicine, September, 1971, pp. 980-986.

[28] Kramer, Edward F., and others. "Physiologic Effects of an 18-Hour Flight in F-4C Aircraft," Aerospace Medicine, November, 1966, pp. 1095-1098.

of adrenal stimulation, an index of stress, were noted to be significantly less in more experienced pilots.

After an excellent review of the concept of fatigue, Perelli presented the results of observations made on subjects flying varying schedules in a flight simulator.[29] Results showed disruption of circadian rhythm to be a greater source of fatigue than duration of activity. Interestingly, the more simple tasks were most impaired by intense fatigue.

Though the results of Perelli's study have significant applications to flight operations, the flying environment part of the fatigue equation was excluded. One of the few studies directed towards evaluation of the environmental component alone was published by Storm in 1973.[30] Subjects performed various tasks in four different environments: (1) low humidity, ground altitude; (2) low humidity, 8000 feet altitude; (3) moderate humidity, ground altitude; (4) moderate humidity, 8000 feet altitude. The flying environment above 25,000 is essentially dry and it was thought this dryness might cause fatigue. The study, however, suggested that there was no performance decrement and no increase in fatigue in a high altitude, low humidity environment.

Laboratory studies have not generally been used to study causes of fatigue. Such an approach was alluded to in an early study by Miller and Ginsberg entitled "Metabolic and Serologic Changes in Flight Fatigue." They measured blood sugar, BUN, creatinine and basal metabolic rates in a small number of fliers following flights. Though reaching no conclusions,

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[29] Perelli, pp. 1-186.

[30] Storm, William F., and others. Effects of Low Humidity on Human Performance, USAF School of Aerospace Medicine, Report SAM-TR-73-3, February, 1973, pp. 1-20.

they expressed hope that further studies would be performed. They also alluded to the occupational health importance of such studies: "It is hoped that these facts will not only prove of academic interest but will be useful in the future welfare of those men engaged in aeronautics."[31]

In summary, the main thrust in recent aircrew fatigue studies has been operationally oriented, looking at various workloads and the fatigue they produce. Measurements of physiologic or biochemical parameters have not been intended to look at the causes of flight fatigue. Rather, they have served the following purpose (as described in a literature review commissioned by the Air Force):

> Since fatigue results from expenditure of physical and/or chemical energy by the body, it is likely that the amount of certain metabolic products would be strongly correlated with the degree of fatigue. Measuring the levels of these metabolites in an aircrewman might allow prediction of his ability to perform in the near future.[32]

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[31] Miller, W., and A. Ginsberg. "Metabolic and Serologic Changes in Flight Fatigue," Journal of Aviation Medicine, 2:155, 1931, p. 160.

[32] Biochemical Tests-Aircrew Stress, MRI Project No. 2030-E, Item No. 001, Sequence No. 1, Midwest Research Institute, Kansas City, Missouri, 1980, p. 1.

THE RESEARCH HYPOTHESES AND AN IDEAL MODEL

The research proposal to be described has as its basis the following hypotheses:

1. A given activity or workload, when performed in flight, produces a greater amount of fatigue than when performed in a normal, ground environment. This difference is that part of aircrew fatigue which is associated with the flying environment. We will call this environmental fatigue.

2. Environmental fatigue is caused by changes in body chemistry or physiology produced by a unique environment.

3. The difference between those changes in body chemistries and physiology noted on the ground from those noted in flight are a product of the flying environment.

4. Associations or correlations between the differences described in #1 and the changes described in #3 may be the result of causal relationships. Further studies would be indicated to make this determination.

Using concepts from the preceding discussion of fatigue, we can create an ideal model for studying the hypotheses. A given task or workload would be completed once on the ground and again (in an identical fashion) in the flying environment. Fatigue would be measured in each setting along with other physiologic or biochemical parameters. Differences would be those due to the differences in environments. Differences in biochemical or physiologic parameters which correlated well with differences in levels of fatigue would be suggestive of a causal relationship worthy of further

study. For example, we might measure blood levels of carbon monoxide along with levels of fatigue. If we found that individuals with the greatest elevations in carbon monoxide levels had the greatest increase in fatigue, further studies would be indicated to see if carbon monoxide caused fatigue in flight.

The ideal model would have certain other characteristics. The study group would have to include a randomly selected cross section of aircrew members, as this is the population of interest. In order to increase the statistical power of our findings, our model would employ a large number of subjects. Not only would the task or workload have to be identical in both settings, but the condition of each individual would have to be identical as he entered each setting.

A PRACTICAL MODEL - NAVIGATOR TRAINING

The ideal model just described would certainly be difficult to create. Yet, if we could approximate the model and control for the important variables, valid studies could be conducted. In fact, phases of the Air Force's Navigator Training Program conducted at Mather Air Force Base in California approximate this model. Navigators for not only the United States Armed Services, but also for those of allied countries, are trained at Mather. Following graduation they are assigned to a broad spectrum of aircraft.

Each day from eight to ten five-hour training missions are flown in T-43 aircraft. The T-43 is a Boeing 737 aircraft which has been modified, replacing passenger seats with navigator training stations. Missions are generally flown at thirty-two thousand feet. Each mission is flown by twelve student navigators with three instructor navigators and two pilots. During these missions, students practice navigational skills under the supervision of their instructors. In another phase of their training, students "fly" similar missions in ground simulators. The tasks they complete in the simulator are essentially the same as those performed in the air.

It is the fact that the students complete similar missions, once on the ground and again in the air, that provides an opportunity to approximate the ideal model described previously. There are two aspects of the student navigator's workload which made it similar in both settings. First, in both settings, the activity is one-dimensional. The student plots a course using readings from different instruments. In contrast, even in

the more modern pilot simulators, the demands or tasks are quite different from those experienced in flight. Second, if the student navigator performs poorly, whether in the simulator or in flight, the result is the same - academic failure. In contrast, errors made by a pilot in actual flight might be more costly.

Despite these similarities, there are some significant differences in the workloads. First, the tasks will not be identical in both settings. There is some variation in demands as the student goes from the simulator to the actual flight. Also, we know from our discussion of workload earlier that identical tasks impose different workloads on different individuals. In other words, each student will experience a different workload. In order to partially control for this variable, we would use the results of a workload related questionnaire (Attachment 2--"After Mission Questionnaire," Q4) in the statistical analysis of the data.

How does this "experiment in nature" conform to the ideal model in other ways? First, would the student navigators be a randomly selected, representative sample of aircrew members? In that (1) most students graduate and become line Air Force navigators and (2) navigators represent approximately 25% of aircrew members in the Air Force (data from Air Force Military Personnel Center, Randolph Air Force Base, Texas); we might at least say they are representative. However, we can not say they represent a cross section of aircrew members. We would have to include pilots and representatives of a host of other crew positions to achieve this. However, this would be partially controlled for as aircrew members must meet roughly the same mental and physical standards. As will be discussed later, the selection of subjects will not be random.

Second, would we have a large enough study population to generate meaningful results? Because each flight includes 12 students and there are some 550 students in training at any given time, there is an opportunity to generate large numbers. This will be discussed further in the section dealing with the mechanics of the study.

Third, would the condition of the subjects as they begin the simulator flight be identical to that before the actual flight? Obviously it would not. Two things could be done to minimize the effects of the variable. First, we could request that students maintain similar schedules for the days preceding each flight (Attachment 3--<u>Instructions to Participating Students</u>). Second, using a questionnaire (Attachment 1--<u>Before Mission Questionnaire</u>, Q2), we can attempt to control for this variable in our statistical analysis. In the discussion of fatigue presented earlier we mentioned that fatigue can be carried over from previous days (acute versus chronic fatigue). By measuring the changes in parameters from start to finish of a flight, rather than only at the end of a flight, we partially control for this "carry over." Hopefully, using the results of the questionnaire in our statistical analysis, we can even further minimize the effect of this variable.

Despite the problems described above, the program at Mather still represents a unique research opportunity. Previous studies have had to <u>create</u> a study population and a research scenario, all at considerable cost. With a small investment of resources and by making observations on what is already taking place each day at Mather, the following study could be conducted.

The study would be a prospective, comparative observational study of fatigue (the dependent variable) and various biochemical parameters (the independent variables) in student navigators at Mather Air Force Base, California. A fatigue directed questionnaire and a blood sample before and after (1) a simulator mission and (2) an actual flight of similar duration would provide the data base. The increase in fatigue and changes in biochemical parameters during the simulator flight would be compared with the increase in fatigue and changes in biochemical parameters during the actual flight. The difference between these two sets of data would represent that which was produced by the environment of flight. Statistical analysis would attempt to correlate the dependent variable (fatigue) with the independent variables (measured biochemical parameters). Positive correlations would be the basis for further studies to determine if a causal relationship exists. Because fatigue is dependent upon workload and workload (as described earlier) is not constant from flight to flight and subject to subject, an attempt to control for this variable will be made. Also, because fatigue can be carried over in varying degrees from previous days, an attempt will be made to control for this variable. In both cases, control will be attempted using the quantified results of a questionnaire.

<u>Independent Variables</u>

The independent variables to be measured would include (1) a screening panel of 24 blood chemistries, (2) plasma osmolality, and (3) carboxyhemoglobin. Because such a comparative study has never been performed, it seems justified to look at a broad spectrum of parameters. Also, with today's automated testing apparatus, a larger number of tests can be performed with little additional serum and at little additional cost.

A number of blood chemistries have been looked at in other studies. The measurement of adrenal hormones as an indicator of stress in flight has already been described. Russell Burton did look at glucose, lactate, and fractionated CPK's in a flight related situation.[33] However, the stiuation studied was high-G simulated aerial combat maneuvers in a centrifuge. The results from this study are not felt to be applicable to aircrew fatigue other than that seen in this type of very physically demanding flying.

In another study by Russell Rayman, hematologic parameters were measured in a small number of aircrew members while they flew a very high sortie rate during an emergency airlift to Cambodia in 1974.[34] No consistent results were found, though once again, the numbers were very small. In none of the studies reviewed in which some biochemical parameter was measured (except for the dry atmosphere study) was a measurement performed while the identical activity was performed on ground.

Though the dry atmosphere study described earlier suggests dehydration is an unlikely contributor to aircrew fatigue, plasma osmolality will be measured. The dry atmosphere in pressurized aircraft has long been thought of (if only on an intuitive basis) as a major contributor to flight fatigue.[35] It is possible that Storm's subjects drank enough during the study to maintain a good state of hydration. A busy aircrew might not.

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[33] Burton, Russell R. "Human Response to Repeated High G Simulated Aerial Combat Maneuvers," Aviation, Space, and Environmental Medicine, November, 1980, pp. 1185-1192.

[34] Rayman, Russell B. "The Cambodian Airlift," Aviation, Space, and Environmental Medicine, May, 1977, pp. 460-464.

[35] Lodeesen, p. 52.

Measurement of carboxyhemoglobin levels would be performed even though there is some evidence suggesting carbon monoxide poses no threat to the health or performance of fliers. The maximum carbon monoxide level measured in an analysis of commercial airlines cabin atmosphere was five parts per million.[36] A group from the Naval School of Aviation Medicine measured carboxyhemoglobin levels in individuals breathing various concentrations of carbon monoxide at various altitudes. While breathing 50 parts per million of carbon monoxide at 10,000 feet altitude, the measured carboxyhemoglobin level in one individual was only 7.5%.[37] The lowest carboxyhemoglobin level at which measurable impairment seems to occur is around 2%.[38] Breathing five parts per million would produce levels far lower than those required to produce impairment. However, the Navy study also demonstrated that symptoms produced by carbon monoxide are dependent upon, not only the level of exposure, but also the duration of exposure.[39] Also a study performed at the Institute of Environmental Stress by the University of California demonstrated that during conditions of elevated carboxyhemoglobin and reduced oxygen tension, in which no performance decrement was noted, an alarm reaction (increased heart rate, blood pressure,

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[36] Vieilleford, H., and others. "Characteristics in the Atmosphere of Long-Range Transport Aircraft Cabins," Aviation, Space, and Environmental Medicine, June, 1977, p. 504.

[37] Lilienthal, J. L., and others. "The Relationship Between Carbon Monoxide, Oxygen, and Hemoglobin in the Blood of Man at Altitude," The American Journal of Physiology, January, 1946, p. 353.

[38] Mikulka, Peter. "The Effects of Carbon Monoxide on Human Performance," Annals New York Academy of Sciences, October 5, 1970, p. 409.

[39] Lilienthal, p. 357.

and ventilatory rate) was elicited.[40] These last two findings suggest that there is a possibility that prolonged exposure, at altitude, to low levels of carbon monoxide, not known to produce impairment, could exact some physiologic cost thereby contributing to fatigue.

Further support for the possibility of low levels of carbon monoxide contributing to fatigue is provided in an article by Arthur DuBois, M.D. He questions the validity of the industrial standard of 50 parts per million. He cites several studies that show that the effects of carbon monoxide extend in a straight line from zero. The dose-response curve is not a hockey-stick pattern with a safe zone of no effect.[41]

In addition to the chemistries just described, additional chemistries or parameters could be included for measurement in the study. A letter would be sent to the Army and Navy Schools of Aviation Medicine describing the study and suggestions for other measurements would be considered.

The Dependent Variable

In that fatigue is difficult to define, let alone measure; deciding how to measure the dependent variable is no easy task. There were three components to the definition of fatigue presented initially: (1) impairment (tissue condition), (2) work output, and (3) subjective fatigue. As pointed out in the discussion of the concept of fatigue,

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[40] Christensen, Carol L., and others. "Effects of Three Kinds of Hypoxia on Vigilance Performance," Aviation, Space, and Environmental Medicine, June, 1977, p. 497.

[41] DuBois, Arthur B. "Establishment of 'Threshold' CO Exposure Levels," Annals New York Academy of Sciences, October 5, 1970, p. 426.

any one of these components may be missing while fatigue is present. Thus, an ideal, complete measurement of fatigue would include measurements from each of these components.

Of all three components, subjective fatigue is the most straightforward and easily measured. In many of the Air Force studies described earlier, the same standard subjective fatigue check list was used (see Q1, Attachment 1). From answers to questions about how the subject feels at that point in time, a numerical fatigue index is assigned. A score of greater than twelve represents no fatigue. A score of eight to eleven represents moderate fatigue. Scores of less than eight suggest severe fatigue.[42] The check list is well validated and results are consistent.[43] This would be the tool used to measure subjective fatigue in this study.

Measurement of work output is less straightforward. Various methods have been used in studies of aircrew fatigue. In Perelli's study of simulated long duration flight, computer measurements of performance in a flight trainer were used.[44] More realistic, though less precise, measurements of aircrew work output were obtained in a British Air Force study.[45] Using a special recording device, they were able to measure the pilot's deviations from the desired heading and altitude. The approach

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[42]Storm, William, and Merrifield, p. 7.

[43]Pearson, Richard G., and George Byars. The Development and Validation of a Checklist for Measuring Subjective Fatigue, Report 56-115, School of Aviation Medicine, December, 1956, pp. 1-16.

[44]Perelli, pp. 1-185.

[45]Jackson, K. F. Pilot Performance in Aircrew Fatigue in Long Range Reconnaissance, Royal Air Force Institute of Aviation Medicine, August, 1965, pp. 1-23.

used in the 43 hour transport flight study described earlier was to have the performance of the aircrews periodically rated by a flight examiner.[46]

In the proposed study, the students are given a numerical grade for their performance on each mission. This would provide a readily available measure of output. Obviously, any student's grade on a given day is determined mostly by his abilities and experience. However, the data of interest would be the difference between performance in the two settings. This could represent fatigue as well as any measure used in previous studies.

Probably the most difficult part of the fatigue equation to measure is impairment or tissue condition. As noted earlier, measurement of adrenal output has often been used as an indicator of physiologic cost, stress, or fatigue. The problem is that which of these three items is measured is uncertain. A simpler and more readily obtained index of tissue condition is sleep. What seems intuitively obvious has been seen in studies of aircrew fatigue. With increased fatigue, increased sleep follows.

The index of fatigue for this study would be a composite of three things: (1) a numerical index of subjective fatigue, (2) a numerical score for performance of the mission, and (3) the hours of sleep following the flight.

Before describing the actual mechanism of the study, some general remarks concerning a study involving fatigue are in order. There are a number of facets of the entity of fatigue and a myriad of factors that are thought to cause fatigue. This makes the results of any study involving fatigue suspect and often difficult to reproduce. It would be tempting to

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[46] Harris, pp. 980-986.

perform this study without looking at fatigue. If we found a three percent increase in plasma osmolality during the actual flight which was not seen during the simulator mission, it might be quite significant regardless of its relationship to fatigue. Yet, obtaining an index of fatigue is relatively easy, and for all those reasons presented in the introductory remarks, learning more about aircrew fatigue is an important objective.

CONDUCTING THE STUDY

Preparations

The ideal organization through which this study might be conducted would be the United States Air Force School of Aerospace Medicine located at Brooks Air Force Base, Texas. The School of Aerospace Medicine has on-site consultant services in physiology, biochemistry, aerospace medicine, and statistics. The School has done the bulk of recent studies in aircrew fatigue and has more "corporate experience" in this area than any other agency.

The study could be completed by a physician or physiologist assigned to the School. Residents in Aerospace Medicine are expected to complete a project during the year they are assigned to the School. This study would be ideally suited for the completion of that requirement.

The first step would be to submit the proposal for review (and hopefully approval and sponsorship) to the Aircrew Technology Division of the School of Aerospace Medicine. Once this was obtained, the following steps could be initiated. The time sequence is outlined in Attachment 4.

First, the researcher would have to insure that the necessary approval and support could be obtained. This would involve the following organizations or people; command level (Air Training Command Surgeon), base level (323rd Flying Training Wing Commander), squadron level (the Navigator Training Squadron Commander), and the students themselves. That the study would be conducted through the School of Aerospace Medicine would give it considerable credibility. However, the use of blood sampling

would demand that the purpose and methodology of the study be carefully described. Venipuncture within 24 hours of a flight is prohibited and will require a waiver from the Command Surgeon. Also, voluntary participation by students will be sought. Participation will be more likely if the study is presented favorably.

Headquarters for the Air Training Command is located at Randolph Air Force Base, also in San Antonio. A letter would be sent to the Command Surgeon describing the study and requesting his permission. A waiver to perform the venipuncture before flights and a waiver for confidentiality (see Attachment 3) would be requested.

Having obtained command approval, the researcher could then take the first step in acquiring base level support - recruiting one of Mather's five flight surgeons to help with the study. A letter would be sent, explaining the study and requesting the assistance of one interested flight surgeon. The Flight Surgeon's Office at Mather is one of the busiest in the Air Force. The letter would acknowledge their busy schedule and explain that their participation would primarily involve enlisting approval and support for the study. (Local flight surgeons generally enjoy excellent rapport with base flying personnel.) The local flight surgeon would also coordinate a few details and be available to draw blood the days of the study. By writing a small part of the final report he would become a co-author on the final report.

The local flight surgeon would hand carry a letter from the School of Aerospace Medicine to a scheduled appointment with the Wing Commander. He might want to send a copy to the Commander before the

appointment. He would explain the purpose and importance of the study and obtain his approval. Once this is accomplished, the same process would be repeated in acquiring the approval of one of the Undergraduate Navigator Training Squadron Commanders. Here the rapport of the local flight surgeon with the flying squadron would be especially important. The local flight surgeon could first approach his assigned UNT Squadron Commander. Once he had his approval, he could recruit the third and final member of the research team--a project officer from the UNT Squadron being studied. The ideal project officer would be the scheduling officer from the squadron. However, any of the squadron's instructor navigators would be acceptable. The squadron project officer and the local flight surgeon could address the students in the squadron, describing the purpose and importance of the study and asking for volunteers. The provisions assuring student confidentiality would be reviewed along with other parts of the "Instructions to Participating Students" handout (Attachment 3). An adequate number of subjects would be 48. This would represent four T-43 flights. With approximately 70 students in each squadron, a 49% participation rate would be required. If fewer than 48 students volunteered, another squadron would be approached. Insufficient voluntary participation by one of the squadrons would prevent conducting the study as described.

Such selection precludes a random sample. If all or most all students volunteered, a random selection could be conducted as students are randomly assigned to each squadron.

Once the necessary approval and support has been secured, the logistical preparations for the study could be initiated. The preparation requiring the longest lead time would be the scheduling of the simulator

and T-43 flights. As stated previously, the missions to be studied would be routine training missions performed as part of the training program. Creating special missions for the study would incur considerable cost unnecessarily. Early scheduling would insure that flights would meet training requirements and the requirements of the study. The scheduled activities of the day before the simulator and actual flights should be the same. The simulator and actual flights should begin at the same time. By scheduling all study flights closely together, the blood samples could all be analyzed together with minimal storage effect. Storage effect could be even further minimized by having two of the four study groups fly the T-43 first while the other groups would fly the simulator first. An ideal schedule would have all groups in the classroom for a full day on Monday. On Tuesday morning Groups A and B would begin a simulator flight at 0800 and Groups C and D would begin an actual flight at 0800. On Wednesday all groups would spend the day in the classroom. On Thursday Groups A and B would fly in the T-43 while Groups C and D would fly a simulator mission.

The squadron project officer has three other important tasks. First, he would ascertain if any changes could be made in the simulator workload making it more closely resemble the actual flight without interfering with training. Second, he would give the students their instructions before the study. Third, he would review the schedule of events for the days the study is conducted to insure that timetables are realistic. By briefly describing the flight and simulator missions in the final report he would become a co-author of the study.

The local flight surgeon would have only a few easily accomplished tasks. First, he would contact the Mather Lab and reserve the services of

two laboratory technicians adept at venipuncture for the time periods before and after each flight. Because syncope in Air Force aircrew members requires a medical evaluation, all blood samples would be drawn in the recumbent position. The flight surgeon would be responsible for securing a litter or cot for this purpose.

Other preparations would be the responsibility of the researcher from Brooks. The three remaining major areas of preparation would be (1) preparing and reproducing questionnaires, (2) acquiring the necessary supplies and equipment, and (3) arranging for laboratory analysis of the specimens. He would also insure that the time table for all preparations was followed carefully.

There would be two separate questionnaires. One would be completed prior to each mission; the other, after. The Before-Mission Questionnaire would include the standard Air Force subject fatigue questionnaire described earlier. It would also include the set of questions (described previously) used to control for "carry-over fatigue" (Attachment 1). The After-Mission Questionnaire would include the subject fatigue questionnaire as well as the questions described earlier controlling for the variable, workload. An adequate number of questionnaires would be reproduced before the study.

The supplies required are listed in Attachment 5. These could be acquired through Supply at the School of Aerospace Medicine. They consist primarily of items for taking blood samples.

Arranging for the laboratory analysis of the specimens is probably the most important preparatory step next to enlisting the cooperation of the students. The primary researcher would rely heavily upon the research laboratory at Brooks for advice on how to insure high quality analysis of

specimens. The specimens would most likely need to be analyzed by a commercial laboratory in Sacramento. Planning for this would need to be accomplished well before the study is conducted.

With adequate planning and preparation, as described, conducting the study would be relatively easy. The optimum schedule for the four different "study flights" was described earlier. The local flight surgeon and one laboratory technician would work with the simulator group while the Brooks researcher and the other laboratory technician worked with the T-43 groups. Questionnaires and blood samples would be completed after the pre-flight briefing immediately before the simulator missions or flights. Because of the long time required to pre-flight the aircraft on the actual flights, data/sample collection would have to be done aboard the aircraft.

Though blood samples would be obtained as soon as possible after all four missions, the post flight questionnaire would be completed by the student on his own three to four hours after completion of the mission. A finding in several studies measuring subjective fatigue was that minimal fatigue was felt at the conclusion of a flight while considerable fatigue was noted hours later.

The final data would be collected the day after each mission. Each student would notify the project officer of his hours of sleep the night after the mission. Also, the project officer would collect the mission scores from the Instructor Navigators.

STATISTICAL ANALYSIS

The researcher would work with the consultant in statistics at the School of Aerospace Medicine in reviewing and performing the statistical analysis. The following is an outline of the steps required in testing the research hypotheses.

Preliminary Calculations

Following completion of the missions, the following raw data would be available from each subject: (1) two sets of before- and after-mission blood chemistries, (2) two sets of before- and after-mission questionnaires, (3) two sets of mission performance scores, and (4) two sets of recorded after-mission hours of sleep.

The first step would be to convert the results of the questionnaires to numerical data. The numerical values for the subjective fatigue index portion of both questionnaires (Q1) is derived by adding two points for each check in the "better than" column, one point for the "same as" column, and zero points for the "worse than" column. In order to make increasing values represent increasing fatigue, the results would be subtracted from 20. Subtracting the before-mission subjective fatigue value from the after subjective fatigue value would yield the increase in subjective fatigue for that mission. This would be designed $SF_{m,n}$ where "m" represents the mission ("f" for flight, "s" for simulator), and "n" represents the subject number.

The numerical value for the parameter we referred to earlier as "Carry Over Fatigue" is obtained by adding the numbers appearing before each circled reply in Q2, "Before-Mission Questionnaire." The same applies

to obtaining a value for "Workload," assessed in Q3, "After-Mission Questionnaire." The sum of the value for Workload and Carry-Over Fatigue would represent a Variable Fatigue Index. In order that increasing values for this number correctly represent the potential for increasing the amount of fatigue in the study, the Variable Fatigue Index would be subtracted from 18 (the maximum possible value) to yield Variable Fatigue, designated $VF_{m,n}$. Once again, "m" would represent the setting and "n" the subject number. By subtracting the Variable Fatigue for the simulator from that for the flight, the Change in Variable Fatigue (ΔV_n) is calculated.

In order to add the increase in subjective fatigue, hours of sleep, and performance scores, while weighing all parameters equally, they would have to be converted to a common scale. This would be done by calculating the percentage of the observed range of results represented by each figure and multiplying this by ten. For example, if the range of increases in subjective fatigue for all simulator and flight missions was -1 to 5, the range would be 6. An observed value of 2 would be converted $[(3 \div 6) \times 10]$ to 5 (on a scale of 0 - 10). In order for decreasing performance scores to represent increasing fatigue, observed performance scores would have to be subtracted from maximum points possible before being converted to the common scale. The sum of the converted values would represent a "Fatigue Index," designated $FI_{m,n}$. The differences between the Fatigue Index of the flight mission and the simulator mission for each student could be calculated ($FI_{f,n} - FI_{s,n}$). The results would be designated ΔF_n, or Change in Fatigue, subject n.

The final preliminary calculations would involve the biochemical data. The differences between before- and after-mission values for each

parameter would be calculated. This figure would be labeled $Pi_{m,n}$, or Biochemical Parameter i for setting m, subject n. The difference between each subject's simulator and flight values ($Pi_{f,m} - Pi_{s,n}$), for each parameter, would be calculated and labeled Pi_n, Change in Parameter i for subject n.

Analysis of Fatigue

The first statistical analysis would be directed towards confirming the first of the research hypotheses; "A given activity or workload, when performed in flight, produces a greater amount of fatigue than when performed in a normal, ground environment." This would be accomplished using a multiple linear regression model:

$$FI_{m,n} = B_0 + B_1X_m + B_2V_{m,n}$$

$FI_{m,n}$ = Fatigue Index for setting m, subject n

B_0 = Intercept

X_m would equal 1, if m = f(flight); 0 if m = s (simulator)

B_1 is a coefficient which defines how $FI_{m,n}$ (fatigue) regresses on (or changes with) the setting (f or s). We test our research hypothesis by testing $B_1 = 0$. (There is no difference in fatigue in the two settings.) B_2 is a coefficient which defines how $FI_{m,n}$ changes with the variable $V_{m,n}$ (which we control for). Computer analysis would define the statistical significance of the hypothesis that there is a difference of fatigue in the two settings.

Analysis of Biochemical Parameters

The next step would be to define those biochemical parameters for which there was a significant difference in the change in the simulator compared to the change in flight. A paired t-test would be used to compare

(for each parameter) the mean of observed changes in the simulator ($Pi_{s,n}$) with those in the flight ($Pi_{f,n}$).

$$Td = \frac{\bar{d}}{Sd/\sqrt{n}}$$

Td is a test statistic which equals the mean of the differences over the sample standard deviation of the differences, divided by the square root of the number of subjects. Sd/ n is the standard error.

$$Sd = \sqrt{\frac{\sum(d-\bar{d})^2}{n}}$$

where d represents the individual differences.

If $Td \geq t_{n-1,\ 1-\frac{0}{2}}$, then we can reject the null hypothesis that there is no significant difference between the two sets of changes. $t_{n-1,1-\frac{\alpha}{2}}$ is a t distribution with n-1 degrees of freedom and α is the desired p value, generally .05. We can replace the standard symbols with the terms used in our study to yield the following formula:

$$Td = \frac{\overline{\Delta}\, Pi}{Sd/\sqrt{n}}$$

$$Sd = \sqrt{\frac{\sum(Pi - \bar{P}i)}{n}}$$

Correlation Between Fatigue and Biochemical Changes

The final step in the analysis would be to see if there is a correlation between (1) the increase in fatigue seen in the flying environment and (2) that increased change seen in those biochemical parameters for which a significant change was noted. This would be accomplished with a multiple linear regression analysis. The following model could be used:

$\hat{\Delta F}_i = B_0 + B_1 \ \Delta Pi_n + B_2 \ \Delta V_n$

$\hat{\Delta F}_i$ = Differences between the change in fatigue seen in flight from that seen in the simulator, subject i.

B_0 = The intercept

B_1 = A coefficient which defines how $\hat{\Delta F}$ changes with changes in ΔPi_n.

Pi_n = The difference between the changes in biochemical parameter i, subject n, seen in the flight environment from that seen in the simulator environment.

B_2 = A Coefficient which defines how $\hat{\Delta F}$ changes with $\hat{\Delta V}_n$

$\hat{\Delta V}_n$ = The difference between Variable Fatigue recorded for the flight and that for the simulator mission, subject n. This is controlled for.

Computer analysis of the null hypothesis that $B_1 = 0$ will define whether there is a linear relationship between the increase in fatigue and the increased change in a particular biochemical parameter.

Results

The statistical analysis would fulfill and complete the objectives of the study. Three important questions would be answered: (1) Is the fatigue experienced in the flying environment greater than that experienced on the ground while performing the same task? (2) Are there biochemical changes which occur to a greater degree in the flying environment than on the ground while performing a given task? (3) Is there a correlation between these biochemical changes and the differences in fatigue observed in the two settings?

The researcher might wish to hypothesize reasons for any observed correlations and suggest what further research might be undertaken to explain such correlations.

If no correlations are found, at least one approach to the study of aircrew fatigue will have been explored. Possibly five or ten years from then, the same research design could be used again, employing new and more sophisticated laboratory studies or new and more refined measurements of fatigue.

Attachment 1

BEFORE-MISSION QUESTIONNAIRE

NAME AND GRADE			TIME/DATE
INSTRUCTIONS. Make one and only one (✓) for each of the ten items. Think carefully about how you feel RIGHT NOW.			
STATEMENT	BETTER THAN	SAME AS	WORSE THAN
1. VERY LIVELY			
2. EXTREMELY TIRED			
3. QUITE FRESH			
4. SLIGHTLY POOPED			
5. EXTREMELY PEPPY			
6. SOMEWHAT FRESH			
7 PETERED OUT			
8. VERY REFRESHED			
9. FAIRLY WELL POOPED			
10. READY TO DROP			

PREVIOUS EDITION WILL BE USED

SAM FORM SEP 76 136 SUBJECTIVE FATIGUE CHECKCARD

Q1.

Q2. The following questions are to be answered prior to the mission. Circle your reply.

The total number of hours of sleep I have had in the last 48 hours is . . .

1. 0 - 8   2. 8 - 16   3. 16 - 24

(greater than 24, see your flight surgeon for evaluation for narcolepsy)

Though the following replies might not come close to describing the kind of day I had yesterday, the one that comes closest is:

1. Hectic, very busy - worked very hard. Had more to do than I could handle.

2. Average - fairly busy but had time to relax. Worked moderately hard.

3. Easy - relaxed mostly.

Though the following replies might not come close to describing the way I have felt in the last 24 hours, the one that comes closest is:

1. Poor - very tired or in poor health or pressing emotional problems or stress

2. Fair - mild fatigue or very minor illness or emotional stress

3. Good - not tired, not ill, no significant emotional stress (knock on wood)

Attachment 2

AFTER-MISSION QUESTIONNAIRE

NAME AND GRADE			TIME/DATE
INSTRUCTIONS. Make one and only one (✓) for each of the ten items. Think carefully about how you feel RIGHT NOW.			
STATEMENT	BETTER THAN	SAME AS	WORSE THAN
1. VERY LIVELY			
2. EXTREMELY TIRED			
3. QUITE FRESH			
4. SLIGHTLY POOPED			
5. EXTREMELY PEPPY			
6. SOMEWHAT FRESH			
7 PETERED OUT			
8. VERY REFRESHED			
9. FAIRLY WELL POOPED			
10. READY TO DROP			

Q1.

SAM FORM 136 SEP 78 SUBJECTIVE FATIGUE CHECKCARD

PREVIOUS EDITION WILL BE USED

Q3. The following questions are to be answered after the completion of the mission. Circle the correct answer.

I would judge the difficulty of this mission as:

1. Difficult
2. Average
3. Easy

I found the amount of time I had to complete my work on this mission:

1. Inadequate
2. About right
3. Excessive

The amount of work (calculations, plotting, etc.) I was required to complete on this mission is best described as:

1. Great
2. Moderate
3. Small

Attachment 3

INSTRUCTIONS AND CONSENT FOR PARTICIPATING STUDENTS

The study you are being asked to participate in will provide important information about the effects of flight on the human body. We hope this information might be used to make the flying environment a safer, healthier, and more comfortable place to work.

Because this is a "controlled study," we will be asking certain things of you. We will be comparing information or data obtained before and after a T-43 flight with data obtained before and after a simulator mission. Because we are interested in the effects of flight, the T-43 flight will be our study flight and the simulator flight will be our control flight.

1. Ideally, everything about you and the mission would be the same for the simulator flight and the T-43 flight. Though this is impossible, by observing the following instructions you can make the situations more similar and increase the accuracy of the study. As much as is comfortable for you and without interfering with your training, attempt to make your activities the day before the simulator flight and the day before the T-43 flight as similar as possible. This would include such things as diet, hours of sleep, and exercise. Also, as much as possible, make your activities during the two missions as similar as possible. If you smoke two packs of cigarettes and drink six cups of coffee during the simulator, then stock-up for the T-43 flight. We hope you moderate your

activities but the key is to make your general condition before and during both missions as similar as possible.

2. The drawing of blood samples is the most important part of the study. We regret that it is necessary as we know that it is uncomfortable. However, there is no other way to acquire the needed information. To minimize your discomfort we have gotten the best of the hospital lab's "vampires" to help us. Once again, we appreciate your sacrifice.

3. Assuring your privacy is a promise we make to you. Confidentiality will be secured in the following manner: At the beginning of the study, you will be assigned a number. All data and information will be recorded by this number, not your name. The key (who is assigned which number) will be kept by the researcher from the School of Aerospace Medicine. He will use this key in one situation only. Should laboratory data suggest that an individual had a significant medical problem, the key would be referred to for identification of the individual. The individual would be notified directly by the School of Aerospace Medicine researcher. The researcher would privately tell the student the significance of the finding but otherwise take no other action. Further evaluation would be up to the individual. This is an unusual arrangement for military medicine but it has been approved to facilitate your participation in the study.

4. Consent

_____ I wish to participate in this study. I understand the above information. I also understand that information gained from this study may be used for publication though my confidentiality will be maintained. I also understand that I may withdraw from this study for any reason, at any time.

_____ I do not wish to participate in this study.

____
Signed

____
Print Name

Attachment 4

SCHEDULE FOR PREPARING/CONDUCTING THE STUDY

SW = The week the study is actually conducted

SW minus 8 months	Proposal presented to School of Aerospace Medicine, Crew Technology Division, for approval, sponsorship, and critique.
SW minus 7 months	Final study plan completed, incorporating SAM suggestions.
	Proposal presented to ATC Surgeon for approval and waiver regarding (1) venipuncture, (2) confidentiality.
	With help of SAM statistician, initiate development of statistical tables.
SW minus 6 months, 2 weeks	Deadline for ATC Surgeon's approval.
	Proposal presented to Mather Flight Surgeons requesting participating member.
SW minus 6 months	Deadline for recruiting participating local flight surgeon.
SW minus 5 months, 2 weeks	Proposal presented to Undergraduate Navigator Training (UNT) Wing Commander for approval.
SW minus 5 months	Deadline approval Wing Commander.
	Proposal presented to UNT Squadrom Commander.

SW minus 4 months, 2 weeks	Deadline approval UNT Squadron Commander.
	Schedule presentation of proposal to squadron.
	Select project officer (co-researcher) from UNT Squadron.
SW minus 4 months	Deadline for having presented proposal to squadron, enlisting student participants.
	Project officer begins coordination of scheduling and begins analyzing missions to make them more similar.
	SAM researcher initiates coordination of required laboratory services.
SW minus 2 months	Scheduling complete
SW minus 6 weeks	Local flight surgeon requests assistance from lab technicians for study dates and insures cot will be available.
	SAM researcher: (1) requests necessary supplies (see Attachment 5, "Budget") from Medical Supply at Brooks AFB (2) makes travel arrangements for trip to Mather (3) requests necessary copies of questionnaires from Reproductions Section, Brooks AFB.
	Deadline for coordination for lab services.

SW minus 4 weeks	SAM researcher reviews (over phone) missions and preparations with local flight surgeon and project officer.
SW minus 2 weeks	Deadline for obtaining supplies and questionnaires, and making arrangements with laboratory.
Week before SW	SAM researcher arrives at Mather. Rehearsal (without venipuncture) of study procedures. Briefing of students about procedures, requirements. SAM researcher reviews requirements with lab. Meeting of three member research team to review details.
Monday of SW	All groups, normal classroom academic day.
Tuesday of SW	AM - Groups A & B - Simulator mission Groups C & D - T-43 flight
Wednesday of SW	AM - All groups, normal classroom academic day. Post-flight questionnaire, grades, sleep records collected.
Thursday of SW	AM - Groups C & D - Simulator mission Groups A & B - T-43 flight PM - Blood samples for both mission days submitted to laboratory.

Friday of SW	AM - Post-flight questionnaires, grades, and sleep records collected.
	PM - Results collected from laboratory by SAM researcher. SAM researcher returns to Brooks.

Attachment 5

BUDGET

Discussion

The following budget is based on the assumption that the study would be conducted, as described, through the School of Aerospace Medicine. No attempt is made to calculate the value of the primary researcher's time or that of the consultants. The cost of expendable items was obtained from the Medical Supply Section at the School of Aerospace Medicine. The costs of laboratory tests were obtained from a commercial laboratory (National Health Laboratories, San Antonio, Texas). Whether the tests could be completed in a military facility (probably at a reduced cost) would depend upon the availability of services.

The items included on the chemistry panel are listed after the costs. As mentioned in the discussion of the independent variables, there are two reasons why such a broad spectrum of chemistries would be studied. First, none have been studied in a controlled setting before. Second, an automated panel of chemistries can be run at a relatively low cost using a small amount of serum.

As opposed to the chemistry panel, the cost of determinations of carboxyhemoglobin and plasma osmolality is quite high. The cost of doing 192 determinations of each might be prohibitive. There are three possible solutions to this dilemma. First, there is the possibility of having the tests run in mass at a government lab. This might reduce the cost to an acceptable level. Second, a limited pilot study could be

constructed to look at these two variables alone before including them in the larger study. Last, and probably least acceptable, these parameters could be determined on only a portion of the specimens. This would make the statistical analysis more difficult and less valid. The first option is optimal and the prices used below are based upon the assumption that they could be run in a government facility at one half the commercial cost.

Costs

Item	Cost/Item	Number Required	Total Cost
10cc vacuum blood tubes	$137 for 50	250	$685
needle with barrel	$50.23 for 1,000	250	$ 13
alcohol wipes	$0.84 for 100	300	$ 3
gauze pads	$2.08 for 200	400	$ 4
SMAC-24 (automated chemistry panel)	$9.95 each	192	$1,910
Blood carboxyhemoglobin	$12.10 each*	192	$2,323
Serum Osmolality	$8,48 each*	192	$1,628
Expenses for Researcher's Trip to Mather (7 days)			$1,050
TOTAL			$7,616

Not included: Value for time required of (1) primary researcher, (2) SAM Consultant, Aircrew Technology Division, (3) SAM Consultant in statistics, (4) clerical support.

*See Budget Discussion

Chemistries Included in SMAC-24 Panel

glucose	LDH	sodium
total protein	alkaline phosphatase	potassium
albumin	SGPT	chloride
globulin	BUN	CO_2
A/G ratio	creatinine	electrolyte balance
total bilirubin	BUN/Cr ratio	calcium
GGTP	triglycerides	phosphorous
SGOT	cholesterol	uric acid

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VITA

Douglas R. Douville was born in Springfield, Missouri, on October 21, 1947. He is the son of Arthur and Eleanor Douville of Overland Park, Kansas. Douglas graduated from Shawnee Mission West High School, Overland Park, Kansas, in 1965. He attended the University of Kansas from 1965 to 1967 and the United States Air Force Academy from 1967 to 1971. In June 1971, he graduated from the Academy with a Bachelor of Science Degree in Life Sciences. In August 1971, he began medical school at the University of Kansas, graduating in September 1974. Following medical school, he served a three year residency in Family Practice at Scott Air Force Base, Illinois. After completion of this residency in 1977, he served as a family practitioner, flight surgeon, and consultant to Environmental Health at Mather Air Force Base, Sacramento, California until 1980. From 1980 to 1981 he served as a family practitioner and flight surgeon in the Republic of South Korea at Osan Air Base. In 1981 he returned to Mather and served in the same capacity as before from 1981 until September 1984. In October 1984, he began work on a Masters Degree in Public Health at the University of Texas and completed this degree in June 1985. He is currently a second year resident in Aerospace Medicine at Brooks Air Force Base in San Antonio, Texas. Dr. Douville is a Diplomat of the American Academy of Family Physicians and a Lieutenant Colonel in the United States Air Force. He is married to Patricia D. (Jensen) Douville.

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